Comparison of Management Strategies for Squash Bugs (Hemiptera: Coreidae) in Watermelon

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ABSTRACT Two watermelon pest management practices, a squash trap crop and a standard recommendation using soil-applied carbofuran, were compared using large-scale field plots to assess trap crop suitability as a replacement for the standard in 2000, 2001, and 2002. In both systems, foliar insecticide applications were used to control squash bugs when populations exceeded threshold levels. During 2001 and 2002, a treatment of untreated watermelon was used. Early season adult insects, from seedling to fruit set, are most critical for watermelon. Significantly fewer early adult bugs were found on watermelon in the trap crop than in the standard recommended practice in 1 of 3 yr. In both years, significantly fewer adult squash bugs were found in watermelon in the trap crop than in untreated fields. The standard recommended practice significantly reduced adult squash bugs in watermelon compared with the untreated in 1 of 2 yr. There was no significant correlation of watermelon yield and squash bug density, indicating that squash bug densities were too low to impact yield. Although squash bugs were reduced significantly by the trap crop, marketable watermelon yields were lower in the squash trap crop than in untreated watermelon, suggesting that pest management treatments may interfere with crop productivity factors other than squash bug colonization. Results suggest that mid-season production squash bug should be managed by monitoring populations and using insecticides as needed rather than using at-plant treatment. Further research is needed to compare treatments during early-season production.

KEY WORDS cucurbit pests, trap crop, carbofuran

WATERMELON, *Citrullus lanatus* (Thunberg, Matsumura & Nakai), is an economically important horticultural crop grown in the southern region of North America. Approximately 16,000 ha is grown in the south central states of Texas and Oklahoma (USDA 1999). The squash bug, *Anasa tristis* (De Geer), is an important and widespread native pest of cucurbit crops in North America that is capable of causing considerable damage to cucurbit crops such as squash and watermelon (Quaintance 1899; Beard 1935, 1940; Metcalf and Flint 1962; Fargo et al. 1988; Nechols 1985, 1987; Bonjour et al. 1990; Edelson et al. 2002).

Squash bugs may kill small plants and parts of larger plants. Squash bugs prefer pumpkin, *Cucurbita pepo* variety *pepo* L., followed by squash, *C. pepo* variety *melopepo* L., and watermelon (Metcalf and Flint 1962, Bonjour et al. 1990). Edelson et al. (2002, 2003) reported significant squash bug damage to watermelon seedlings and mature plants and negative effects on yield. The most significant damage caused by squash bugs may be attributed to feeding by overwintered adults when they move onto newly emerged cucurbit seedlings in the spring. At the seedling stage, one squash bug can kill numerous plants in a very short time (Weed and Conradi 1902, Edelson et al. 2002).

More abundant squash bug populations were found on early-planted (6 May) cucurbits than on those planted later at Stillwater, OK (Palumbo et al. 1991). Overwintered squash bugs were first detected on 17 April, in Atoka County, Oklahoma, and adult squash bug emergence from overwintering sites was completed by 8 June (Pair 1997). Cucurbit crops planted after migration of overwintered adults may escape damage because the adults settle, feed, and remain in fields that have emergent crops present during the spring migration (Eichmann 1945).

Traditionally, many growers in the southern region of the United States try to market melons before 4 July because of the greater value of the crop during the 4 July holiday. This requires planting of watermelon by April, which coincides with the time of emerging overwintered adult squash bugs in southern Oklahoma (Bolin and Brandenberger 2001). Therefore, management of squash bug is necessary in early-planted watermelon. Generally, carbofuran (Furadan 4 F) is applied to the soil as a preventive treatment for early- to mid-season pest control in watermelon (Bolin and Brandenberger 2001).

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Historically, several cultural management practices have been described for controlling squash bug populations. Early-planted squash either on field borders or between rows of other cucurbits may be used as trap crops. Squash bugs that move onto the trap crop from overwintering sites can be hand picked from the trap crop (Weed and Conradi 1902), thus leaving the other later emerging crop with no or low infestations.

Before the development of effective synthetic chemical insecticides, there were few options available for adequate control of many insect pests. Trap crop techniques were an important option that offered an inexpensive and effective control measure (Hokkanen 1991). Quaintance (1899) reported that early-planted squash plants could be used as a trap crop for management of squash bugs in other cucurbits and in squash when planted before the main squash crop.

Results from recent studies using small experimental plots (18.5 by 15.2 m) indicate that using squash as a trap crop around cucumber (Radin and Drummond 1994) and watermelon (Pair 1997) are potential options for management of cucumber beetles and squash bugs in these crops. However, to determine whether a trap crop system can be recommended to producers, it is advisable to evaluate the use of the technique on a commercial production scale. In addition, currently recommended management practices make use of insecticides that are under review by the United States Environmental Protection Agency as required by the Food Quality Protection Act of 1996. This review could lead to cancellation of critical insecticides and could leave growers with no effective insect management options. Insecticides under review include carbamate and organophosphate products that are currently approved and recommended for cucurbits. The objective of this study was to compare the effectiveness of the trap crop management system (without pesticides that are under Environmental Protection Agency [EPA] review) with standard recommended practices for controlling squash bugs and to test the applicability of the trap crop system under commercial production.

Materials and Methods

Cucurbit pest management strategies were compared in 2000, 2001, and 2002 using randomized complete block design experiments with three replications in 2000 and 2002 and five replications in 2001. Treatments consisted of pest management regime options for the key pests in watermelon. Treatments were as follows.

1. Standard Recommended Practice. Furadan 4 F (carbofuran, FMC Corporation Agricultural Products Group, Philadelphia, PA) was applied to fields at a rate of 0.112 kg ([AI])/1000 m in an 18-cm band over the seed furrow at planting. However, in 2002, Furadan 4 F was mixed applied to the base of seedlings during transplanting. Seedling plants were monitored weekly to determine whether insect populations exceeded a threshold of two adult squash bugs per plant. When populations exceeded thresholds, foliar applications of Thiodan EC (endosulfan, Universal Crop Protection Alliance, Eagan, MN), or Capture 2 EC (bifenthrin, FMC Corporation Agricultural Products Group) were to be applied to the watermelons.
2. Trap Crop System. Summer squash seedlings 'Peto 391' were transplanted in border rows at outer edges of watermelon fields before emergence or transplanting of watermelon. Monitoring and control of pests in the trap crop and watermelon were conducted as with the standard recommended practice except that foliar applications of Thiodan EC or Capture2 EC were used only on squash and not on watermelon.
3. Untreated. Watermelon was planted without a trap crop and was not treated with insecticides in 2001 and 2002. In 2000, untreated watermelons were not included in the study.

Soil tests were conducted on all the fields and fertilizer was applied during seedbed preparation based on Oklahoma Cooperative Extension Service recommendations (Motes and Roberts 1994). Herbicides and fungicides were applied to watermelon fields as needed. Fields also were hand hoed and cultivated to control weeds. To prevent treatment-overlapping effects, with exception of one location in 2001, ≈100 m or more distance was maintained between adjacent experimental plots. In 2001, a minimum distance of 30 m occurred between corners of two plots at one location.

Trial I. The 2000 study was conducted at three locations in Oklahoma, the Wes Watkins Agricultural Research and Extension Center (WWAREC) at Lane, the Oklahoma State University Vegetable Research Station at Bixby, and the Caddo Research Station at Fort Cobb. Each location constituted a replicate block of the experiment. Two fields, ≈0.4 ha, were selected at each location and randomly assigned one of two treatments; trap crop system or standard recommended practice. In the third week of May, two rows of yellow summer squash plants, 'Peto 391', were transplanted along the perimeter of one field at each location. Watermelon, 'Jubilee', was seeded at the same time. Watermelon plants were spaced 0.9 m apart within the row and rows were 3.65 m apart. Watermelon and squash at Bixby and Ft. Cobb were irrigated by sprinkler irrigation and drip irrigation was used at Lane.

Field Sampling. In the trap crop system fields, 16–22 squash plants (dependent on length of squash rows) were visually examined weekly for squash bug adults and nymphs. In the same fields, 20–26 watermelon plants (dependent on field size) from the outermost rows on both sides of the field and from one or two rows in the interior of the field were selected for examination. In the standard recommended practice watermelon fields, depending on field dimensions, 16–28 watermelon plants from the first rows at the perimeter of the field and one or two watermelon rows in the interior of the field were selected. Plants were visually examined once each week until fruit maturation. For each sample, all plant structures (leaf, stem, and petioles) and the soil surface immediately underneath each plant within a 40-cm radius of the stem were visually examined for the presence of squash bug adults and nymphs.

In the absence of a documented action threshold for squash bugs in watermelon, the current practice is to use a best estimate action threshold for squash bugs in watermelon. For this study, we chose an action threshold of two adult squash bugs per plant.

Trial II. The 2001 study was conducted at four locations in Oklahoma. There were two replicates at Lane (WWAREC), and one each at Ft. Cobb, (Caddo Research Center), El Reno, (USDA–ARS Grazinglands Research Facility), and Caney (commercial production fields). At each location, three watermelon fields measuring ≈46 by 80 m were established, and one of the three treatments was randomly assigned to each field. The fields were plowed, disk harrowed, and seedbeds prepared for planting. Each field was divided into 16 (11 by 20-m) subsampling units to be used for insect sampling and yield measurement.

Watermelons, 'Jubilee', were planted the first week of May at Caney, the third week of May at Lane, and the second week of June at Ft. Cobb and El Reno. This trial included three treatments: standard recommended practice, trap crop system, and an untreated field. For the trap crop system treatment, one row of squash 'Peto 391' was transplanted on the outermost rows of one field at each location on the same date that watermelons were direct seeded. At Lane and El Reno, drip irrigation was used for watermelon and the trap crop. The fields at Ft. Cobb and Caney received overhead and no irrigation, respectively.

Trial III. The 2002 study was conducted at three locations in Oklahoma: at Lane (WWAREC) and in grower fields at Bennington and Leon. Three fields were selected at each location as described for trial II. At all locations, watermelon, 'Legacy', seedlings were transplanted during the last week of April. Squash, 'Peto 391', seedlings were transplanted at the same time with watermelon seedlings. At Bennington, 7 d after transplanting, seedling death was observed in the standard recommended practice field. Approximately 50% of the seedlings died, and these were replaced within 1 wk with additional transplants. The experimental design and sampling procedures were identical to those used in 2001. Plant culture procedures were similar to those of 2001 with the exception that carbofuran and fertilizer were applied during transplanting using a soluble nutrient source (20-20-20) that was mixed with water and applied at a rate of 0.372 kg/1000 m of row during transplanting. In 2002, irrigation was not used at any location.

Field Sampling. Sampling procedures were modified for trials II and III compared with trial I. For trial II and III, each field was divided into 16 subsampling units overlaid on the portion planted to watermelon. The rows of squash plants were divided into eight subsampling units. Each subsampling unit was assigned a number, and three plants per subsampling unit were randomly selected at each sampling to be visually examined for squash bug adults and nymphs. A total of 48 plants from the watermelon portions of fields and 24 plants from the squash trap crop were visually examined on each sampling date. The plot numbers were recorded on field maps to mark location and movement of squash bugs within the field. Plants were examined for squash bug adults and nymphs as described in trial I, and sampling was terminated when fruits reached maturity.

To estimate fruit yield, sections of watermelon rows 6 m in length were randomly selected for harvest. One row section was harvested in each of the previously described 16 subsampling units. All watermelon fruit within each row section were harvested and weighed. Watermelon fruits of all sizes that had deformities such as severe bottleneck were classified as nonmarketable. Watermelons weighing 6.5 kg or more and lacking deformities were classified as marketable.

Statistical Analysis. Observations of squash bug adults and nymphs were analyzed for each sampling date. However, due to the importance of pests during the early growth stages of watermelon, sampling events also were grouped into two (early and late) sampling periods. The early sampling period consisted of the period from seedling stage to fruit set, and the late sampling period consisted of the time period from fruit set to fruit maturity. Insect abundance data were analyzed using PROC MIXED, and watermelon yield data were analyzed using PROC GLM (SAS Institute 1997). Fisher's least significant difference (LSD) method was used for means separation. To determine the effect of insecticides applied to the trap crop foliage on squash bug abundance in watermelon, insect counts in watermelon before and after insecticide applications were compared using PROC TTEST (SAS Institute 1997). Regression analysis was conducted to determine the relationship between insect abundance and yield using PROC REG (SAS Institute 1997). Squash bug abundance per plant was calculated for the early sampling period and correlated with total (marketable plus nonmarketable) watermelon yield per plant.

Results

Trial I Insect Abundance. In 2000, squash bug populations on watermelon never exceeded the action threshold of two squash bugs per plant (Table 1). No significant difference in adult insect abundance was detected between treatments during the early sampling period ($F = 0.16$; df = 1, 739; $P = 0.6869$) or the late sampling period ($F = 1.35$; df = 1, 488; $P = 0.2464$). Abundance of adult squash bugs on watermelon was similar across the treatments during the early sampling period (Table 1). During the late sampling period, however, nymphal populations on standard recommended practice-treated watermelons were significantly greater than on watermelon in the trap crop system fields ($F = 4.09$; df = 1, 488; $P = 0.0437$).

Table 1. Squash bug densities (±SE) on watermelon grown under different management systems

Yr	Treatment[c]	Mean density of squash bug nymphs (no./plant)			
		Early sampling[a]		Late sampling[b]	
		Adult	Nymph	Adult	Nymph
2000	Trap crop	0.08 ± 0.02a	0.03 ± 0.02a	0.36 ± 0.06a	0.11 ± 0.06b
	Standard	0.07 ± 0.02a	0.01 ± 0.001a	0.27 ± 0.05a	0.48 ± 0.17a
2001	Trap crop	0.02 ± 0.01b	0.03 ± 0.03a	0.16 ± 0.02c	0.22 ± 0.10b
	Standard	0.06 ± 0.01a	0.05 ± 0.02a	1.01 ± 0.10a	1.07 ± 0.22a
	Untreated	0.07 ± 0.02a	0.02 ± 0.02a	0.60 ± 0.05b	1.43 ± 0.29a
2002	Trap crop	0.15 ± 0.02b	0.00 ± 0.00a	1.16 ± 0.08a	1.60 ± 0.25a
	Standard	0.19 ± 0.03b	0.00 ± 0.00a	1.11 ± 0.08a	0.86 ± 0.28a
	Untreated	0.30 ± 0.04a	0.01 ± 0.00a	0.97 ± 0.07a	1.10 ± 0.25a

Means, within years, in a column followed by same letter are not significantly different using Fisher's protected LSD ($P > 0.05$).
[a] Early sampling represents pooled data from seedling stage to fruit set.
[b] Late sampling represents pooled data from fruit set to maturity.
[c] Management system treatments are trap crop, squash trap crop; standard, standard recommended practice; and untreated, no management.

In 2000, within trap crop system fields, foliar insecticides applied to the squash trap crop ($t = -2.58$, df = 95, $P = 0.0113$) reduced the number of squash bugs on these plants (Fig. 1). However, no significant changes in adult squash bug abundance on watermelon during this same time period were detected ($t = 0.38$, df = 296, $P = 0.7036$) (Fig. 2). In 2000, squash bug abundance in watermelons within trap crop system fields did not exceed the action threshold (Fig. 2), whereas it frequently did on squash (Fig. 1).

Trial II Insect Abundance. In 2001, at Ft. Cobb, squash bugs were not found during early or late sampling periods, and data were not included in the analysis. During the early sampling period at the other locations, densities of adult squash bugs differed ($F = 5.10$, df = 2, 2397, $P = 0.0061$) across treatments (Table 1). During the late sampling period, squash bug adults remained lowest on watermelon in the trap crop fields. The density of adult squash bugs in the standard recommended practice-treated watermelons in the late sampling period was significantly greater than in untreated and trap crop system watermelons ($F = 47.63$; df = 2, 1845; $P = 0.0001$). Untreated watermelons had greater populations of squash bugs than did watermelons in the trap crop fields.

During early growth stages of watermelon, there were few squash bug nymphs, and no differences were detected across treatments. During the late sampling

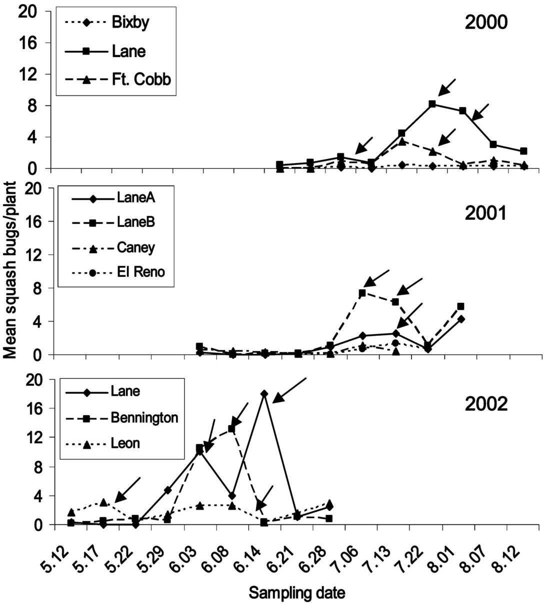

Fig. 1. Adult squash bugs on the squash trap crop and foliar insecticide applications in 2000, 2001, and 2002. The arrows indicate location and time of foliar insecticide applications to the trap crop. Bifenthrin (Capture EC) and endosulfan (Thiodan EC) were alternately used to control squash bugs on the trap crop. The application order was Capture EC, Thiodan EC, and Capture EC.

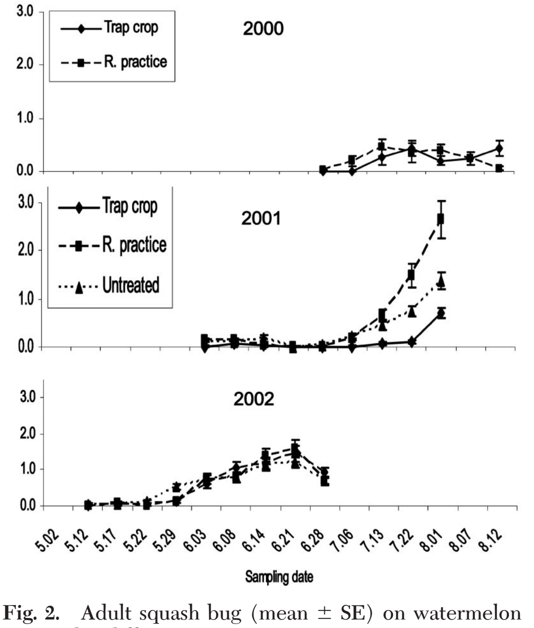

Fig. 2. Adult squash bug (mean ± SE) on watermelon grown under different management systems in 2000, 2001, and 2002. Watermelons were seeded in the fourth week of May 2000 and third of May 2001 and were transplanted in the fourth week of April 2002.

Table 2. Mean total adult squash bug counts on watermelon and the squash trap crop during the early (seedling to fruit set) sampling period in 2001 and 2002

Yr	Treatment[a]	Squash bug counts (no. ± SE/field)[b]		
		Watermelon	Squash[c]	Total
2001	Trap crop	4.00 ± 4.00	32.00 ± 11.99	36.00 ± 13.16
	Standard	12.75 ± 12.42		12.75 ± 12.42
	Untreated	14.00 ± 12.68		14.00 ± 12.68
2002	Trap crop	37.00 ± 23.59	295.66 ± 39.93	332.67 ± 49.36
	Standard	45.33 ± 10.35		45.33 ± 10.35
	Untreated	72.00 ± 30.62		72.00 ± 30.62

[a] Management systems are squash trap crop, trap crop system; standard recommended practices, standard recommended practice; and no management, untreated.
[b] Total number of squash bugs observed in field sampling of the squash trap crop or watermelon during the early sampling period.
[c] Summer squash seedlings were transplanted on the perimeter of watermelon as a trap crop.

period ($F = 8.34$; df = 2, 1845; $P = 0.0002$), populations of nymphs in watermelons were lower in the trap crop than in the other treatments.

Foliar insecticide applications to the squash trap crop reduced squash bug populations on squash plants ($t = -4.28$, df = 83.9, $P < 0.0001$) (Fig. 1) but not on adjacent watermelon plants. Abundance of squash bugs on watermelons in the trap crop fields at the time when insecticides were applied to the squash trap crop either increased or did not change, but did not decrease ($t = 2.47$, df = 165, $P = 0.0144$). This indicates that squash bug abundance in watermelon was not reduced by foliar insecticide application to adjacent squash plants (Fig. 2). Total adult squash bugs on watermelon in the trap crop fields were approximately one-third those of untreated and standard recommended practice fields (Table 2). Although squash plants covered 17% of the field area of the trap crop fields, adult squash bugs on squash were 8 times greater than the number of squash bugs on watermelons in trap crop system fields and 2 times more in standard recommended practice and untreated watermelons (Table 2).

Trial III Insect Abundance. During the early sampling period, untreated watermelons had significantly more adult squash bugs ($F = 7.11$; df = 2, 2155; $P < 0.0001$) than plants in the trap crop and standard recommended practice-treated watermelon fields (Table 1). During this same period, squash bug abundance was similar in watermelons adjacent to the trap crop and those grown under standard recommended practices. During the late sampling period, numbers of squash bugs across all treatments were similar.

We found few nymphs in watermelon during the early sampling period in 2002 and only in the untreated fields. Nymphs were found in all watermelon fields during the late sampling period and no differences were detected among the treatments ($F = 1.57$; df = 2, 1723; $P = 0.2080$).

Similar to previous years, foliar insecticide applications reduced the number of squash bugs on trap crop squash plants ($t = -7.56$, df = 95, $P = 0.0113$) (Fig. 1) but not on adjacent watermelon ($t = 2.03$, df = 343, $P = 0.0428$) (Fig. 2). This indicates that controlling squash bugs on the squash trap crop was not followed by squash bug movement from watermelon to squash.

In 2001, there were fewer squash bugs on watermelons in the trap crop fields during the early sampling period than in the other treatments (Table 2). However, in 2002, there were fewer squash bugs in the untreated fields. Total number of squash bugs on squash and watermelon in the trap crop system fields was approximately 3 times greater than on watermelons in the standard recommended practice and untreated fields in 2001 (Table 2). In 2002, total numbers of squash bugs in both crops (watermelon and squash) in the trap crop fields were much greater than in the other treatments.

Overall, we found fewer adult squash bugs on watermelon in the trap crop fields in 2001 and during the early growth stages in 2002 than in watermelons in untreated fields (Table 1). The effects of the squash trap crop on adult squash bug populations varied across years during late watermelon growth stages. During the early sampling period, there were few squash bug nymphs and no difference was detected among the treatments (Table 1). During the late sampling period, there were fewer nymphs in watermelon in the trap crop than in the standard recommended practice watermelons in 2000 and in both of the other treatments in 2001. In 2002, nymphal abundance did not differ among the treatments.

Watermelon Yield. Watermelon yield data for 2001 and 2002 is shown in Figs. 3 and 4. Neither the standard recommended practice nor the trap crop treatments produced a higher yield than the untreated plots in either 2001 or 2002 (Figs. 3 and 4). The data suggest that marketable yield was reduced in the trap crop compared with the untreated. No significant correlation (data not shown) or linear regression (Table 3) between adult squash bugs and watermelon fruit yields was found in either 2001 or 2002.

Discussion

The objective of these studies was to determine whether a trap crop system, when applied on a commercial production scale, would be a useful replacement for the current standard recommended practice for the control of a major early-season insect pest of watermelon in our area. It was found that the management systems evaluated affected various aspects of

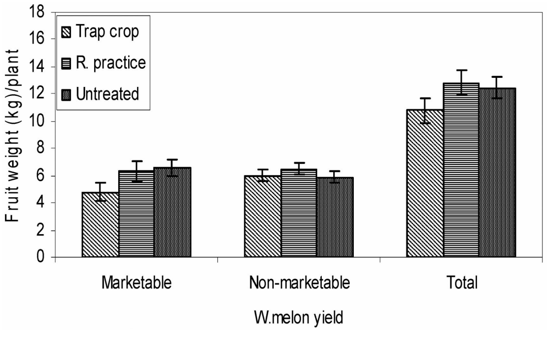

Fig. 3. Marketable, nonmarketable, and total watermelon yield (mean ± SE) under different management systems in 2001. Watermelon fruits without deformities and weighed 6.5 kg or more were grouped marketable. Watermelon fruits with deformities or weighed <6.5 kg were grouped nonmarketable.

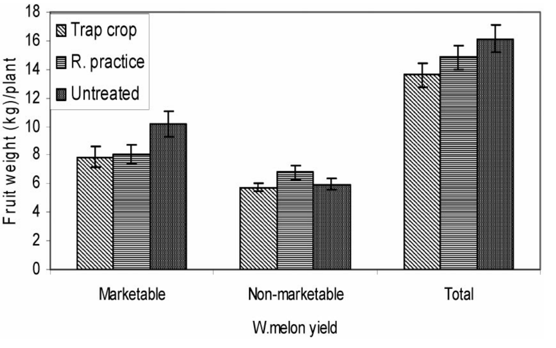

Fig. 4. Marketable, nonmarketable, and total watermelon yield (mean ± SE) under different management systems in 2002. Watermelon fruits without deformities and weighed 6.5 kg or more were grouped marketable. Watermelon fruits with deformities or weighed <6.5 kg were grouped nonmarketable.

watermelon production, including timeliness and magnitude of insect infestation and crop yield. Detection of overwintered adult squash bugs differed across the 3 yr of this study in which planting dates also differed. In 2002, watermelons were transplanted ≈2 wk earlier than the seeding of watermelon in 2001 and 3 wk earlier than seeding in 2000 (Fig. 2). These results for watermelon are similar to the study conducted in summer squash by Palumbo et al. (1991) in which they found greater squash bug populations in early compared with late-planted summer squash. Previous studies have indicated that squash bug adults emerge from overwintering sites by mid-April (Pair 1997) and search for suitable hosts. It can be inferred that planting date may have an effect on colonization of watermelon by squash bugs.

Squash bugs were detected earlier on squash trap crop plants than on watermelon plants in the same fields. Fewer squash bugs were found on watermelons in the trap crop fields than on watermelons in untreated fields. Because adult squash bugs can cause significant damage to watermelon seedlings (Edelson et al. 2002), the management of overwintered squash bug populations is important during early watermelon growth stages. Therefore, attracting squash bugs to a trap crop may delay their entry and subsequent abundance in watermelon, which is important in reducing seedling losses.

The effect of the management systems on adult squash bug abundance in watermelon during the late sampling period varied across years in that treatment effects were detected only in 2001. This suggests that neither the trap crop system nor the standard recommended practice management system is reliably effective for management of squash bug populations during the later watermelon growth stages. Management of squash bugs in watermelon after the fruit setting stage may not be cost-effective (Edelson et al. 2003). However, squash bug control during the late watermelon growth stages is recommended for the reduction of overwintering populations as an overall approach to management in successive years (Pair et al. 2004). Practices other than those used in this study should be explored for the control of potential overwintering populations.

Watermelon in the trap crop system fields produced lower marketable fruit yields in 2001 and 2002 than did untreated watermelon. However, the squash trap crop in combination with insecticide application to squash reduced squash bugs in watermelon compared with untreated fields. Therefore, the cause of yield reduction in watermelon was not directly attributable to squash bug abundance in watermelon. Similarly, watermelons receiving the standard recommended practice treatment, which included the use of carbofuran, did not produce marketable fruits yields that were greater than untreated watermelons (Fig. 3). This is in contrast to studies by Foster and Brust (1995) in Indiana that demonstrated watermelon yield increases from carbofuran application that were attributed to effects other than insect control.

Table 3. Regression analysis for squash bug at various stages and yield on watermelon grown under different management systems

Yr	Variable	Intercept (95% CI)	Slope (95% CI)	P	r^2
2001	Adult	12.12 (6.85, 17.38)	−5.53 (−17.33, 6.27)	0.3057	0.1485
	Nymph	12.59 (7.02, 18.16)	−2.99 (−8.30, 2.32)	0.2251	0.2018
	Total (bugs/sample period)	12.94 (7.63, 18.25)	−1.74 (−4.52, 1.45)	0.1864	0.2346
2002	Adult	10.36 (4.34, 16.37)	0.32 (−2.75, 3.39)	0.8106	0.0088
	Nymph	10.76 (7.46, 14.06)	0.12 (−1.27, 1.51)	0.8505	0.0054
	Total (bugs/sample period)	9.55 (5.18, 13.91)	0.22 (−0.37, 0.81)	0.4047	0.1010

Means of the pest combinations were regressed on mean yield per plant for each treatment.

Although many abiotic and biotic factors can result in yield reduction, it is possible that nontarget effects of treatments, including disruption of pollinators by the trap crop system, may have resulted in watermelon yield reductions. Studies have shown that bee species were very effective at pollination in organically grown watermelon. However, conventional watermelon growers experienced greatly reduced bee activity, resulting in insufficient pollination in watermelon compared with organically grown watermelons (Kremen et al. 2002).

Previous studies indicated that squash bugs would not attack watermelon plants when alternative host plants such as pumpkin and squash are present (Eichmann 1945, Bonjour et al. 1990). However, when watermelon is the only host available, squash bugs can cause significant damage to early-planted watermelon, which is a common practice in the southern regions of Oklahoma and northern Texas. Because planting dates used in our study were more indicative of mid-season watermelon production, further studies are required to evaluate the effect of trap crops and at-planting carbofuran application for controlling early emergence of overwintering squash bugs in watermelons. Based on our results with mid-season watermelon production, the most effective pest management strategy may be to monitor and treat with insecticide when squash bug populations exceed threshold levels. More research is needed to establish the necessary economic and action thresholds for squash bug in watermelon in the region to enable recommendations for such an approach.

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